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THE AUTOKINETIC TEST AS A MEASURE OF INTROVERSION-EXTROVERSION¹

MARCIA HELEN VOTH²

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PROBLEMS

The phenomenon of autokinetic streaming, the perception of apparent movement of a stationary pinpoint of light in a totally dark room, has long been known as a laboratory item. The first scientific observation of its occurrence is dated 1799 and was made by Von Humbolt as reported by Voth (19). Since then many others have noted the phenomenon, but for a long time little scientific significance was attached to it in the sense of its having any utilitarian value. In recent years, however, autokinetic streaming has been used as one means of predicting remission and improvement in cases of schizophrenia, first by A. C. Voth (19) at State Hospital, Topeka, Kansas, and later by M. C. Sexton (18) at State Hospital, Columbus, Ohio.

Traditionally, the assumption has been that schizophrenics are the extreme of introversion, and it has been observed that in extreme cases the individual is indeed completely withdrawn into himself; he has no contact with the outer world of reality. Both Sexton and Voth have observed that the amount of movement seen by a patient on the Autokinetic test decreases, in some cases to a zero point, as a cure is attained. It would seem, then, that the Autokinetic test might be a measure of introversion-extroversion not only in abnormal cases, but also in normal individuals.

This experiment has been set up to determine the relationship between scores on the Autokinetic test and scores on other tests commonly used as measures of introversion-extroversion.

MATERIALS AND PROCEDURE

Thirty subjects were chosen at random from the women students; ten each from the sophomore, junior, and senior classes. They were asked if they would assist in an experiment which would require taking four tests of personality involving a total of about three or four hours of their time. They were assured that the results would be kept confidential, and that the primary interest was in group rather than individual scores. They were told that, if they wished, after the

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experiment was finished they might secure their results and also any other information they might desire on what was being done.

The first test administered was the Bernreuter Personality Inventory, one of the oldest and best known of the paper-and-pencil types of personality survey. It consists of 125 questions to which the subject is required to give a "Yes," "No," or "?" answer. The fact that it measures several different personality traits at once prevents the subject from discerning exactly what factor of his personality is being investigated. Six scales for scoring have been constructed involving various personality traits: B1-N, neurotic tendency; B2-S, self-sufficiency; B3-I, introversion-extroversion; F1-C, self confidence; and F2-S, sociability. The B scales are those devised by Bernreuter, and the F scales are those devised by J. C. Flannagan (3). In this experiment the B3-I, F1-C, and F2-S scales only were scored.

This test was administered in a group situation with the subjects using separate answer sheets to facilitate scoring. The instructions on the test proper and on the answer sheet were read aloud while the subjects read them silently:

The questions on this blank are intended to indicate your interests and attitudes. It is not an intelligence test, nor are there any right or wrong answers. In front of each question you will find; "Yes," "No," "?". If your answer is "Yes," draw a circle around the "Yes." If your answer is "No," draw a circle around the "No." If you are entirely unable to answer either "Yes" or "No" to the question, then draw a circle around "?."

Do not write anything on the test folder. First, read the directions at the top of the first inside page. The three columns of answers on this sheet are to replace those on the test folder. By folding under columns two and three, column one can be readily matched with the first page of the test. By refolding, the second page can be marked; and by unfolding the third page, column three is available to substitute for the third page of the test. Make sure you answer every question. (1)

The second test administered was the Minnesota T-S-E Inventory. This test was developed by Evans and McConnell (2) to measure three types of introversion-extroversion: thinking, social, and emotional. Thus, it is not a measure of a single undifferentiated trait, but of three types of a trait that have been statistically isolated by Guilford (5). This, like the Bernreuter, was administered in a group situation. The T-S-E test has detachable answer sheets which the subjects used. The directions on the test were read aloud while the subjects read them silently:

This test contains questions about your behavior and reactions in different situations. The results will help you better to understand your personality adjustments. There are no right or wrong answers. There is no time limit, but you should work as rapidly as possible. Do not spend too much time on any one question. Be perfectly frank and try to answer each question as accurately as you can.

Before beginning the test, tear off the back page which is the answer sheet. Then open the test booklet and place the answer sheet so that the number on the answer sheet matches the number of the page on which you are working. You will see that there are five vertical spaces following each question on the test.

Indicate your answer to each question by filling in one of the vertical spaces in pencil, according to how frequently your behavior or reaction is the same as the question asked.

A—always or almost always your behavior is the same as in the question. F—frequently or often your behavior is the same as in the question. O—occasionally or sometimes your behavior is the same as in the question. S—seldom or rarely your behavior is the same as in the question. N—never or almost never your behavior is the same as in the question.
(2)

The Autokinetic test was administered in the college dark room which is absolutely light proof. The subject was taken into the room and seated at a table which was approximately 12 or 15 feet from the source of light. This was an ordinary container holding a low watt bulb and a black screen, the purpose of the screen being to cut off all but the direct ray of light. The can was concealed by a paper during the instructions, and every effort was made to avoid giving the subject any impression of the nature of the experiment or placing any particular value on either seeing or not seeing movement of the light. The table was equipped with a large sheet of ordinary wrapping paper, about 30" by 40". The subject was given a heavy beginner's pencil, and the following instructions were read (adapted from Voth, (19)).

When the room is darkened, you will see a tiny pinpoint of light directly in front of you where you see the paper now. You are to fix your eyes on the light and hold your head as steady as is comfortable. Now, make a heavy dot approximately at the center of the paper. You are to consider this dot as the normal position of the light, and the paper as the total visual field around the light. If, during the test, you should see any movement of the light, you are to draw a continuous line graph of the movement as accurately as you can, both as to speed and direction, starting from the center dot. Any stops the light might make from time to time you are to indicate by a heavy black dot. If the light should carry your pencil off the paper, return it to where you guess the center to be and continue from there. Under no other circumstances are you to move the pencil or take it from the paper. As long as you see no movement, keep the pencil at the center starting point. If you do not see the light immediately after the room is darkened, do not be alarmed; it takes a little time for you to become accustomed to the dark. When the test is over, in 10 minutes, I will switch on the light again. Now place your pencil at the center dot. Are you ready?

The room was then darkened, the paper was removed from the light, and the subject was left alone for the 10 minutes.

After this test was over the subjects were told that the object of the experiment was to determine whether this particular test was a measure of any factor of personality. It was stated that almost every one tended to see some type of movement, although some did not, and that what each person did see varied markedly from individual to individual leading one to believe that some factor of individual differences was at the basis of this phenomenon.

The last test given was the Rorschach inkblot test. This test was developed by Rorschach and first appeared in 1921. It consists of ten cards which have on them ordinary inkblots, some black, some red and black, and some multi-colored. Most of the subjects were familiar with the Rorschach test in some form, either from having taken the Harrower-Erickson group test their freshman year in connection with another experiment, or from the recent publicity about such psychological tests, particularly in the motion pictures.

The test was given in one of the college dormitory rooms for single occupants.

The subject was seated in a comfortable chair beside the experimenter's desk in such a position that the experimenter could see each card as the subject was describing what she saw. Each subject was requested to schedule her appointment at a time when she would not be hurried in any way. Every effort was taken to make her feel at ease, and care was taken that no distractions occurred during the test. To her were read the instructions, as given by Hertz.

I am going to show you some cards, one by one. The cards have on them designs made up of ink-blots. I want you to take each card in your hands, look at it carefully, and tell me what you think it could be, what it looks like to you. You may hold the card anyway you wish, but be sure to tell everything that you see in the design. When you have finished with a card, you may lay it face down on the desk and I will give you the next one. Do not wait for any signal from me. (This was added to meet the situation.) If you do not understand, you may ask me any questions. For example, look at this sample blot, (a "home-made" one), and tell me what you think it could be. What does it look like to you?

The test proper was then given.

RESULTS

Tables I and II give the scores for the 30 subjects of each of the tests.

The Bernreuter Inventory was scored for the B3-I scale, the F1-C scale, and the F2-S scale. The raw scores were converted into percentiles given by Bernreuter in the *Manual for the Personality Inventory* (1) for college women. The coefficients of reliability as given by Bernreuter (1) are as follows: B3-I = +.85, F1-C = +.86, and F2-S = +.78.

Raw scores for the Minnesota T-S-E Inventory on each of the three scales were converted into percentiles as given in the *Preliminary Manual for the Minnesota T-S-E Inventory* (2). These were based on scores of freshman and sophomore men and women. The coefficients of reliability as given by Evans and McConnell (2) are as follows: T = +.91, S = +.88, and E = +.75. A fourth score for the T-S-E Inventory was also computed by adding the percentiles. This was done to see if any relationship existed between the Autokinetic test and a score representing a sum of various components of introversion-extroversion as defined by Evans and McConnell (2).

Scores for the Autokinetic test were computed by means of the formula given by Voth (19) $\frac{L \times DC \times ME}{\sqrt{(S+1)}}$. Here, L equals the total length of the path of the movement; DC the maximum distance attained from the center; ME the maximum expanse of the graph, that is, the distance between the two points farthest apart in the graph; and S the number of stops. Voth added the integer 1 to prevent the possibility of a zero quotient in case no stops were noted. The measurements were made with a map measure, and all figures were converted into centimeters. In order to obtain a range of scores more nearly approximating the normal distribution curve to facilitate computations, the scores were converted into logarithms to two decimal places.

On the Bernreuter Inventory high percentiles indicated introversion; the T-S-E Inventory high percentiles indicated extroversion; and on the Autokinetic test high scores indicated introversion.

It was more difficult to obtain absolute scores from the Rorschach results. Because of the subjective nature of the test, and because its primary intention is to give the total personality and intellectual picture, to abstract just one feature and to call it a measure of a trait is, in a sense, defeating the purpose. However, out of the total picture of introversion-extroversion it was possible to abstract

TABLE I

SUBJECT	B3-I	F1-C	F2-S	T	S	E	TSE
1.	89	98	16	96	35	94	225
2.	13	13	14	5	88	88	181
3.	53	58	51	40	45	20	105
4.	15	10	22	71	92	91	254
5.	45	58	34	55	93	96	244
6.	64	54	61	71	74	60	205
7.	10	2	72	25	84	25	134
8.	40	22	86	18	74	33	125
9.	74	84	80	50	33	50	133
10.	11	7	62	15	83	40	138
11.	23	43	12	68	32	53	153
12.	4	3	67	3	52	23	78
13.	87	95	56	49	27	94	170
14.	28	28	56	80	40	23	143
15.	18	15	14	63	83	88	234
16.	86	87	21	50	73	30	153
17.	22	33	7	74	55	77	206
18.	18	22	18	15	62	53	130
19.	59	44	15	33	85	80	198
20.	50	36	80	58	73	80	211
21.	8	13	18	80	55	53	188
22.	51	42	74	5	30	30	65
23.	37	54	11	11	38	98	147
24.	19	23	22	52	29	63	144
25.	30	49	42	85	14	28	271
26.	30	13	91	18	18	40	76
27.	56	83	19	78	35	63	176
28.	12	10	34	60	87	63	210
29.	10	9	34	63	45	73	181
30.	64	39	86	16	43	50	109

several ratios which are as follows: $\frac{M}{\text{sum } C}$, $\frac{FM + m}{Fc + c + C'}$, $\frac{8 + 9 + 10}{R}$, $\frac{M}{R}$, $\frac{M + FM + m}{R}$, and sum C.

On the Rorschach test various determinants may influence the type of response given, that is, how it is seen, what it is seen doing, why it looks as it is described. An answer is scored M for human figures in human-like action, FM for animals in animal-like action, m for abstract or inanimate movement, Fc for shading as surface appearance or texture that is differentiated, c for shading as texture that

is undifferentiated, C' for achromatic surface color, FC for definite form with bright color, CF for bright color with indefinite form, and C for color only.

The sum C ratio is found by the following computation: $\frac{FC + 2CF + 3C}{2}$.
 $\frac{8 + 9 + 10}{R}$ is the ratio of the number of responses on the last three cards to the

TABLE II

SUBJECT	$\frac{M}{\text{sum } C}$	$\frac{FM+m}{FC+c+c'}$	$\frac{8+9+10}{R}$	$\frac{M}{R}$	$\frac{M+FM+m}{R}$	sum c
1.	1.00	.67	.30	.10	.30	0.0
2.	.80	1.00	.30	.40	.60	0.5
3.	.38	3.67	.40	.04	.36	7.5
4.	2.00	3.00	.38	.08	.31	0.5
5.	.33	1.67	.42	.05	.31	3.0
6.	.40	2.00	.36	.09	.27	2.5
7.	1.33	6.00	.43	.15	.30	4.5
8.	5.33	1.67	.43	.30	.49	3.0
9.	1.00	5.00	.52	.09	.30	2.0
10.	12.00	5.00	.24	.29	.52	0.5
11.	6.00	9.00	.33	.13	.33	1.0
12.	.40	.50	.56	.06	.19	2.5
13.	2.00	3.00	.32	.11	.26	1.0
14.	1.38	4.00	.27	.18	.32	8.0
15.	.50	1.00	.31	.06	.13	2.0
16.	2.80	5.00	.37	.11	.19	2.5
17.	2.00	1.00	.30	.15	.25	1.5
18.	.67	1.00	.37	.03	.11	1.5
19.	2.50	1.00	.39	.22	.39	2.0
20.	10.00	8.00	.44	.28	.72	0.5
21.	.09	1.20	.49	.23	.16	11.5
22.	4.00	1.36	.44	.20	.38	5.0
23.	6.00	4.00	.35	.30	.50	1.0
24.	1.00	6.67	.18	.14	.29	4.0
25.	6.00	1.50	.35	.23	.35	1.0
26.	2.00	2.00	.39	.17	.50	1.5
27.	1.00	4.00	.36	.09	.45	0.0
28.	1.00	2.67	.20	.08	.28	2.0
29.	.25	2.33	.40	.03	.23	4.0
30.	5.00	1.00	.42	.13	.24	0.0

total number of responses. In each case the scoring symbol stands for the total number of responses of that type on the test.

The ratio $\frac{M}{\text{sum } C}$ is indicative of outer control. "If M exceeds twice sum C, (that is, if the ratio is 2.00 or above) there are indications of too little affective energy in the emotional contact with the outside world due to withdrawal or to repression. When sum C exceeds twice the number of M, (that is, if the ratio is .5 or below) "... there are indications of a lack of necessary outer control

(11). "The ratio $\frac{FM + m}{Fc + c + C}$ represents introversial and extroversial tendencies not fully accepted or utilized by the subject" (11). It bears the same significance as does the $\frac{M}{\text{sum } C}$ ratio. The ratio $\frac{8 + 9 + 10}{R}$ is significant since the last three cards are those made up of bright colors with no black included. Also, because of the construction of the blots it is more difficult to organize the whole into one response, so that a larger number of detail responses are given, that is, a response involving one part of the blot. When this ratio is less than .30, it is an indication of underproduction. This alone had no significance in one particular case, but must be considered along with the above two ratios. If the subject shows underproduction and an extroversial trend on the first two ratios, then a neurotic unresponsiveness to color is indicated. On the other hand, if the subject shows overproduction, .40 or more, and the second ratio shows an unresponsiveness to color, then it appears as an indication of repression of responsiveness to outside stimulation.

M, FM, and m are all indications of various aspects of the subject's inner life, the amount of these factors increasing with the amount of inner life. It is not necessary here to go into the clinical aspects of the various ratios, but it is sufficient to say that they were used in various ways to give scores that might be indicative of introversial or extroversial trends. The sum C figure alone also has no diagnostic significance in the Rorschach technique, but the main significance of color usage lies in the aspect of emotionality. The greater the use of color, the greater the emotional life, so that its main significance lies in its relation to the M responses which indicate the amount of control the subject has over this factor. The justification for its use in the correlations is based on the fact that it, too, is an indication of the inner life of the individual.

Correlations were made by the product-moment method and appear in Table III. A correlation expresses the amount of co-variation between two sets of data, and may vary between the extremes of +1 and -1. Direct relationships are expressed by positive correlations and inverse relationships are expressed by negative correlations. A 0 correlation indicates a complete lack of relationship between the two sets of data. Thus, by correlating scores on a test known to measure a certain trait with scores on a test about which nothing is known, it is possible to determine whether the latter test measures the same factor as the first, the converse definition of the factor, or some factor not measured by the first test.

In order for a correlation figure to be statistically significant, that is, not due to chance, it must be at least three times the standard error of the correlation.

The standard error is computed by the formula $\frac{1}{\sqrt{N - 1}}$, and in this experiment is found to be $\pm .19$. Therefore, it is necessary to have a correlation of at least $\pm .57$. As it can be seen, none of the correlation figures reached this point.

The correlation of .40 between the Autokinetic test and the Bernreuter B3-I scale, and between the Autokinetic test and the Bernreuter F1-C scale does ap-

proach this point, and the probability of this occurring merely by chance is 3 in 100. Thus, the Autokinetic test might be a measure of a person's imaginativeness, self-consciousness, and feelings of inferiority as defined by the Bernreuter Inventory. Nevertheless, it cannot be said that a person scoring high on the Autokinetic test possesses these traits, but only that he might tend toward them.

The negligible correlations between the Autokinetic test and the Bernreuter F2-S scale, sociability, and between the Autokinetic test and the Minnesota S scale would indicate that introversion in the sense of withdrawing from social contacts cannot be measured by the Autokinetic test.

The correlation of .37 between the Autokinetic test and the Minnesota E scale also approaches the point of statistical significance. However, it would be expected that this should have been a negative correlation since high scores on the

TABLE III
Correlations

1. Autokinetic—Bernreuter, B3-I.....	.40
2. Autokinetic—Bernreuter, F1-C.....	.40
3. Autokinetic—Bernreuter, F2-S.....	-.14
4. Autokinetic—Minnesota, T.....	.06
5. Autokinetic—Minnesota, S.....	-.08
6. Autokinetic—Minnesota, E.....	.37
7. Autokinetic—Minnesota, T + S + E.....	.42
8. Autokinetic—Rorschach, M/sum C.....	-.05
9. Autokinetic—Rorschach, M + FM + m/R.....	.21
10. Autokinetic—Rorschach, 8 + 9 + 10/R.....	.03
11. Autokinetic—Rorschach, FM + m/Fc + c + C'.....	-.05
12. Autokinetic—Rorschach, sum C.....	-.26
13. Autokinetic—Rorschach, M/R.....	-.04
14. Bernreuter, B3-I—Minnesota, T.....	.15
15. Bernreuter, B3-I—Minnesota, S.....	-.25
16. Bernreuter, B3-I—Minnesota, E.....	.19
17. Bernreuter, B3-I—Minnesota, T S E.....	.00

E scale indicate extroversion and high scores on the Autokinetic test indicate introversion. This is not as ambiguous as might be thought since the emotional extrovert, according to the definition given by Evans and McConnell (2), tends to make the simple direct response to emotional appeals, whereas the introvert tends to inhibit and repress such outward expression. Thus, it would seem that a person inhibiting his expression of emotion would also inhibit his perception of apparent movement of light.

While there is a fairly high correlation between the Autokinetic test and the sum of the scores on the T-S-E Inventory, it is doubtful whether any significance can be attached to this fact. This test is constructed in three separate parts, and no attempt is made to measure an over-all factor. Further, no norms are given for any such summation, and there is no definition of what such a trait might be. It does offer a suggestion that there is a possibility that such a summation of scores might be indicative of some trait or factor that could be differentiated

or defined on further investigation. It is also suggested that it is negatively associated with the trait as measured by the Autokinetic test.

The lack of relationship between the Autokinetic test and the Rorschach results is, in a sense, to be expected. In the discussion of the Rorschach test it was stated that it is impossible to obtain a score in absolute terms that will correspond to numerical scores or indices. We were only able to break down the total picture of the personality into its various components, no one component in itself being a measure except in its relationship to several others. If it had been possible to arrive at one over-all score or index of introversion-extroversion rather than six components, a more definite relationship between these two measures might have been established.

It is also to be expected that no relationship between the Bernreuter B3-I scale and the individual scores on the T-S-E Inventory would appear. They do not purport to measure the same thing, the former measuring an over-all characteristic and the latter three specific items.

DISCUSSION

The term introversion-extroversion itself is an elusive one. The two types were originally named by C. G. Jung (10), and developed out of his studies of nervous patients in his medical work. He defined introversion thus:

Introversion means a turning inwards of the libido, whereby a negative relation of subject to object is expressed. Interest does not move towards the object, but recedes towards the subject. . . . Introversion is active when the subject wills a certain seclusion in face of the object; it is passive when the subject is unable to restore again to the object the libido which is streaming back from it. When introversion is habitual, one speaks of an introverted type. (10, 567)

The definition of extroversion is the converse of this, a positive movement towards the object.

Jung also differentiated within these two types, four different functions; thinking, feeling, sensation, and intuition. Out of the combinations of type and function, Jung postulated eight different psychological types which form the basic structure of personality. It is out of this beginning that most of the further development of the concepts of introversion and extroversion proceeded. At present the picture has enlarged and changed both through further psychological and statistical investigation of the traits, and through the distortions that inevitably occur as the problem is attacked by many different individuals.

A dictionary definition denotes introversion as interest directed inward, a propensity for finding one's satisfactions in external things. Bernreuter (1), in the *Manual For the Personality Inventory*, says an introverted person is imaginative and tends to live within himself. Evans and McConnell (2), in the *Preliminary Manual for the Minnesota T-S-E-Inventory*, separate three types of introversion-extroversion,—thinking, social, and emotional. The thinking introvert shows a liking for reflective thought, particularly of a more abstract nature, and tends to be less dominated by objective conditions and generally ac-

cepted ideas; the social introvert tends to withdraw from social contacts and responsibilities and displays little interest in people; and the emotional introvert tends to repress and inhibit the outward expression of emotion and feeling, and tends not to make the typical response to simple, direct emotional appeals.

The above are more objective definitions derived from objective measures; that is, they define in terms of outward manifestations of the trait, how the individual reacts in the outer world of people and objects. On the other hand are the subjective definitions of the inner drives and compulsions not necessarily manifested by the individual in his relations with the outer world.

Rorschach (11) attempted to determine various areas of stimulation and their effect on the individual. Thus, he defines the introvert as one who is predominately prompted from within. Moreover, he found that this inward prompting seems to be distributed normally among the population so that the great majority are responsive to stimuli both from within and without with relatively few on either end. He found also that cultural patterns play a great part in the way a person reacts to the stimuli. People may "cover" a basic introversion (in the Rorschach sense) by ease and smoothness in their contacts with people, so that to the observer they appear complete "extroverts" (here in the sense commonly applied by the layman—highly sociable individuals).

Rorschach's interest is not that of experimental investigation of personality types, but rather his interest lies in the source of conflict or maladjustment. Thus, he desires to know not whether an individual is prompted from within or without, but whether these promptings cause conflict. It can be seen that this sort of information cannot be discovered about an individual by the conventional means, that of giving an objective test; for the individual will, on such a test, give the answers in terms of how he actually reacts and behaves rather than how he might subconsciously be driven to act.

There is a further difference in the type of measurement made on the objective tests such as the Bernreuter Inventory and The Minnesota T-S-E Inventory and on the subjective tests such as the Autokinetic test and the Rorschach test. This difference lies in the area of personality within the individual that one wishes to measure. In a sense, the definitions involved in the measurements seem to be mutually exclusive, but in reality a relationship does exist so that they are not incompatible. It is as if two separate scales are involved, one taking into account the inner promptings of the individual and the other the outward manifestations of these promptings. It also appears that these two scales vary independently of each other. Thus, the total picture for each scale would show a few individuals scoring at the extremes and the great majority falling in between. At present there is no measure that bridges this gap between the objective and the subjective.

The Rorschach test and the Autokinetic test measure the subjective features of introversion by setting up a situation in which there are no social norms by which one may measure his responses, so that the individual has no choice but to react as he is inwardly prompted. This appears in the Rorschach test in the form of movement responses. An example will serve to demonstrate what is meant by this. A person not prompted from within will see in one card a pic-

ture of two men. Inquiry shows that these two figures are men because of the outline, their form and shape, they have noses, legs, etc. They may be a cartoon, a caricature, or a painting. On the other hand, the person prompted from within will see the same men dancing, fighting, talking, *doing* something. Anyone will admit that these two figures are not actually moving, but it is the quality of seeming, which at times can be so strong that the subject will actually assume part of the pose while describing the card, that is the indication of the inward promptings.

In the Autokinetic test, again, the hypothesis is that the more introverted individual will project himself into the situation and thus see more movement, in this case apparent movement. The exact physiological or psychological cause of this phenomenon is not known although many theories have been advanced. The one developed by Lewin (13) is most closely related to the theory and structure of the Rorschach test and fits best into the premise that the Autokinetic test measures the inner promptings of the individual. He speaks of a frame of reference for anchorage in a social situation, one that is structured. That is, the individual acts and judges his actions according to the standards of the situation in which he may find himself. In the unstructured situation, such as presented by the Rorschach test and the Autokinetic test, the individual makes his own frame of reference, and it is to this which he responds. This, of course, varies with the individual. Following this theory, it would seem that the extrovert would see little or no movement, while, on the other hand, the introvert converts his inner promptings into movement.

Thus, there is one factor in common in the Autokinetic test and the Rorschach test, the factor of movement, or more explicitly, perception of movement. From this it would seem that a relationship between the scores on these two tests could be experimentally established. This has been shown in a clinical situation by Voth (19) and Sexton (18).

It has been pointed out that there is a discrepancy in the meaning of the terms introversion and extroversion as used in the objective and subjective tests. A further discrepancy exists within the objective tests themselves. This was mentioned in discussing the Bernreuter Inventory and the Minnesota T-S-E Inventory. The former measures the trait *per se*; and the latter breaks it down into three traits.

A great amount of statistical research has been carried on beginning with Cattell (17) and carried through to a large extent by Guilford and his associates (5), (6), (7), (8), (9) and also by others, Layman (12), Rayburn and Taylor (16), (17), and Flannagan (3). Cattell (17) proposed the thesis that introversion is not a unitary trait, but is composed of two independent, bi-polar factors. Rayburn and Taylor (16), (17) went on to isolate four factors, one of which was Cattell's "desurgency"—a dislike for the confusion of social entertainment. The other three were: emotional or conative stability, sociability, and what may be defined as perseveration.

Guilford and Braly (8) in 1930 found that the classification fell roughly into three groups: intellectual, social, and emotional. In 1934, Guilford (5), using Dodd's revision of Spearman's technique with the Thurstone factor analysis on 36 items measuring introversion-extroversion, found a "g" factor, a term used by Spearman to identify a general factor running through many specific traits. This would substantiate the possibility of isolating

a specific factor, introversion-extroversion. However, in 1936, Guilford (6) re-examined the original 36 items by the Thurstone method of factor analysis, and this time found no "g" factor, but instead four different factors, and on a retest, five. He labeled the five factors: S—Social, E—Emotional, and the others, M, R, and T. In 1939, Guilford (7) further investigated the factors and defined R as rhythmia or happy-go-lucky. M and T of the 1936 study he found to break down into several more dimensions, D—Depression, S—Shyness, T—Habitual thinking of the meditative type, LT—Liking for thinking of the problem-solving type, and A—Alertness. He also found that the correlations between D, S, and T pointed to the common conception of introversion-extroversion.

Layman (12), in 1940, further advanced the idea that there is no single trait by conducting an item analysis of items from 16 tests, including the Bernreuter Inventory. He sorted out 16 traits, but none that could be called introversion-extroversion. By further statistical processes he lowered this number to 12 and found the common conception of introversion-extroversion to be a combination of five factors which are: a feeling of social inadequacy; gregariousness (negatively speaking); emotionality, that is, dominated by mood or attitude and colored by emotional trends; low threshold of emotional stimulation; and inability to face reality.

The general conclusion offered by these studies is that few tests adequately discriminate traits. It can also be seen that in the break down of the original trait, there is no single trait or combination of traits that meet the definition as proposed either by the Rorschach test or the Autokinetic test.

The main difficulty lies in the fact that, in the objective type of test, the situation is structured socially; the responses are given in terms of social or external situations and throw no light on the individual's inner compulsions. As mentioned before, our culture plays an important role, demanding of the individual a high degree of sociability, of "getting-alongness," that more or less tends to force him to be able to meet the occasion. This is particularly true of the small liberal arts college where the experiment was conducted. While the sample taken was a random sample, some element of selection had already occurred in the choosing of this particular school. It is more likely that a student will possess a surface or objective extroversion although the inner stimulation may be in the opposite direction.

Thus we have several factors influencing the lack of correlation between the objective measures and the Autokinetic test which are: the small sample; the ambiguity of definitions; the cultural role demanded of the individual in this particular situation.

These same factors also apply to the lack of correlation between the Autokinetic test and the Rorschach test, and a few others may also be postulated. The main one is the difficulty of converting the Rorschach results into absolute scores. Another might be the chance of suggestion entering into the Autokinetic test. While in this experiment every effort was made to prevent the placing of a premium on either seeing or not seeing movement, and while the subjects were asked not to discuss the Autokinetic test until they all had been given, nevertheless, there seemed to be a tendency on the part of the subjects to be pleased with a great deal of movement, and on the other hand to be displeased or disappointed in not seeing much. It is very possible that through the deceptive familiarity on the part of the students with psychological tests, and through an effort to

please the experimenter, there was some premium placed on seeing movement. Voth (19) has shown that there is present within the individual the ability to inhibit or facilitate movement in varying degrees.

SUMMARY

This experiment has been an attempt to measure the relationship between scores on the Autokinetic test and scores on other tests commonly used as measures of introversion-extroversion. This was done by correlating scores on the Autokinetic test with scores on the Bernreuter Personality Inventory, the Minnesota T-S-E Inventory, and the Rorschach Inkblot test. However, no significant correlations were found.

CONCLUSIONS

1. In this experiment it was impossible to come to any definite conclusions as to the use of the Autokinetic test as a measure of introversion-extroversion in normal individuals since no significant correlations were found.
2. The probable reasons for this are as follows:
 - a. The small sample.
 - b. The difficulty of converting the Rorschach results into absolute scores.
 - c. The difficulty of defining introversion-extroversion in terms that fit all of the measures.
 - d. The difference between the personality area measured by the objective Bernreuter Personality Inventory and Minnesota T-S-E Inventory, and the subjective Autokinetic test and Rorschach test.
 - e. The fact that there are no reliability and validity coefficients available for the Autokinetic test and the Rorschach test.
 - f. The similar lack of validity figures for the Bernreuter Personality Inventory and the Minnesota T-S-E Inventory.
3. The fairly high correlation between the sum of the percentiles on the T-S-E Inventory and the Autokinetic test offers a suggestion for further investigation.
4. The clinical observations of Voth and Sexton still need experimental check.
5. This problem itself needs further and more elaborate investigation.

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A COMPARATIVE STUDY OF THE VARIATIONS OF THE POSTRENAL VENA CAVA OF THE CAT AND THE RAT AND A DESCRIPTION OF TWO NEW VARIATIONS

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I. FOREWORD²

The study of the variations occurring in the vena cava posterior of the mammals has long been of interest to anatomists and embryologists. The animals used have been chiefly the cat and man, although significant variations have been found in other animals. The use of the rat in this study was prompted by the small amount of consideration given it in the literature of this subject, and by the availability of a number of specimens at the time of the study.

The work done in the past centers about the contributions of four men, Charles F. W. McClure and E. G. Butler of Princeton University, and George S. Huntington and William Darrach of Columbia University. These men compiled a large amount of information on the occurrence of variations in the cat and in man. A monograph dealing with these variations and offering an ontogenetic interpretation of the variations was published in 1929 (3).

Other contributions have been made to the subject, in one instance dating back to 1543, when Vesalius recorded an example of an atypical left spermatic vein in man. Other contributions in recent years have been by Rotter (1935), Blasingame and Burge (1937), Palazzi (1939), Schall (1926), Von Gierke (1928), Kuhlenbeck (1930), Kodema (1931), Messing and Montagu (1932), Von Skamnakis (1931), and McCormick (1930). A very valuable summary of the past century's study of the Eutherian vena cava inferior was presented by F. P. Reagan (5).

For the most part these men reported variations only in the cat and in man. There has been little written on the variations in the rat. The development of the vena cava posterior of the rat is also incompletely worked out. There seems to have been the same conflict on the origin of this vein in the rat as in the cat and in man. A. S. Begg (1) wrote in 1915 that the vena cava posterior was definitely derived from the R. post cardinal vein. However, in 1928 F. P. Reagan (6) stated that the vena cava posterior was derived, not from the old post cardinal but from a new vein which he called the para-ureteric vein. This vein seems to be somewhat analogous to McClure's lumbar supracardinal system, although Reagan claims that there is no connection between the thoracic supracardinal system and his para-ureteric veins.

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² All plates in this paper were redrawn and prepared for publication by Dr. George D. Morgan, Denison University.

The present study was conducted with thirty-six cats and thirty-six rats from the anatomy classes at Denison University. The specimens were unselected in any way, since they were the ones regularly used in the courses. In addition there are included in the cat specimens one preserved by Dr. George D. Morgan as a notable variation (figure 5), and two from the Ohio State University anatomy laboratories, one of which was normal, the other, a variant (figure 13). The method of procedure was to take the individual cats and rats and dissect the venous and arterial systems of the lumbar region. The internal organs were not removed or damaged in order to leave the specimens in good condition for the other work to be done on them by the classes. Then sketches were made of each animal with reference to variations of all kinds in these vessels. Later the significant variations were decided upon and the final drawings made. The original drawings were done in color to make the relationships of the arteries, veins, and ureters stand out more clearly. A number of the small veins and arteries are omitted in order to simplify the diagrams. Figure 1 is adapted from Huntington and McClure (3). A photograph of the cat from which figure 2 was drawn is included. The research in the literature consisted of searching through the volumes of the Biological Abstracts and the Index Medicus for reports of any pertinent material. Only material actually used in the study was included in the bibliography. For a much more complete bibliography of the field the student should see Reagan's article on the development of the Eutherian vena cava (5).

The general purpose of the study is to further develop the investigation of such variations in the cat and to extend our knowledge of variations in the rat. Upon the discovery of a variation in the cat and in the rat hitherto unmentioned in the literature, the project has taken on the further value of complementing previous work. It is the writer's intention to continue the investigation of this subject beyond the completion of this project in the hope of finding further new variations and more of their causes.

The writer has drawn heavily upon the monograph by Huntington and McClure, "The Mammalian Vena Cava Posterior," for information concerning mammalian embryology and the classification of the types of the vena cava posterior. Practically all of the present paper's section on embryology of the cat and on the classification of the variations was taken from that work.

The writer is indebted to Dr. George D. Morgan of Denison University for his assistance in all phases of the study. Thanks are also due to the students of the comparative and mammalian anatomy classes of the year 1946-1947 at Denison University for the use of their specimens in the study, and to the anatomy department of the Ohio State Medical School for the opportunity to inspect two specimens of the cat and for the privilege of using the medical school library.

The present study is presented by first giving a general embryological background and the possible types of variation which can be expected on an ontogenetic basis. Following this are the variations found in this series of cats and an interpretation of the significance of the variations. The second part of the paper considers the variations found in the rat and how they compare with those of the cat with some speculations as to reasons for the disparities. Finally, conclusions are drawn considering the significance of the study.

II. VARIATIONS OF THE VENA CAVA POSTERIOR OF THE CAT

A. *Embryological Development of the Vena Cava Posterior*

While it is not the purpose of this paper to present in detail the embryology of the lumbar vena cava, it is well to review in outline the course of development. Figure 1 shows diagrammatically the relationships of the three systems of axial veins present at one time or another during the growth of the embryo. This oversimplifies the actual picture, of course, but the general relationships are the ones necessary for an understanding of the adult forms. The reader's comprehension of the adult forms will be greatly aided by a grasp of this composite at the outset.

The principal channels in the lumbar region are the posterior cardinals (A and D), the supracardinals (B and C), and the subcardinals (Subc.). The anastomosing channels form a network about the aorta which allows for a very large number of paths of development. In addition to these three pairs of vessels there is the median cardinal collateral vessel ventral to the aorta. This vein reaches its fullest development later in the history of the embryo, after the subcardinals have dropped out.

At the renal level the anastomoses between the different channels carry the entire flow into the hepatic vein except for the thoracic supracardinals, which continue forward to the heart. These anastomoses form a complete venous ring about the aorta which is called the renal collar.

The relationship of the ureters to the supracardinal and post cardinal veins is clearly shown and the manner in which a periureteric venous ring may be formed when A and B or C and D persist in the same individual.

It will be noticed that the supracardinal veins extend into the thoracic region and form a connection with the heart. It is from these veins and their anastomosing network that the adult azygos vein is formed.

The relative age at which the different systems of veins drop out of use is of utmost importance in determining the likelihood of a particular system's persisting in the adult. The subcardinal veins have reached the height of their development in the 7- to 8-mm. embryo and soon after lose their function entirely except for a small anterior portion which persists as the pars subcardinalis of the vena cava (p. subc.), a segment of the internal spermatic veins, and the adreno-lumbar veins. The subaortic plexus or cardinal collateral channels on the other hand have not fully developed until the 29-mm. embryo. The cardinal collateral vein, which extends through much of the lumbar region at its height, is transitory in the cat but has been shown to be the actual vena cava posterior in marsupials (McClure, 1906). By the time of the appearance of the cardinal collaterals, the supracardinals have taken over the main function of returning the blood to the prerenal vena cava. This makes the chances of the cardinal collateral's persisting very slight. The posterior cardinal veins, however, were the main carriers of the blood previous to the supracardinals and remain important until fairly late in the ontogeny of the embryo. Thus the chance of persistence into the adult stage is relatively good. In fact, the principal forms of atypical vena

cavas are due to the persistence in some combination of one or more of the two supracardinal veins, and the two post cardinal veins. There are fifteen possible combinations, of which one is the normal vena cava.

The different channels present in the embryo have been discussed above but not the actual derivation of the adult vena cava posterior. The iliac veins join the common iliac veins and enter the right subcardinal vein (B). The left common iliac vein also includes one of the intersupracardinal anastomoses (Int. Sprc. Anast.). The iliolumbar veins enter the right supracardinal vein (B) from each side, making use of the anastomoses at that level. The right supracardinal vein (B) then continues craniad until it is joined by the right sex vein. The connection of the right sex vein (S. V.) with the right post cardinal vein (A) is through an anastomosis (Subc. Pc. Anast.). Then the right post cardinal (A) connects with the renal collar. Later the craniocaudal elongation of the renal collar shifts this connection caudad so that the right sex vein enters the vena cava directly, below the renal veins. Next to enter the vena cava are the two renal veins (R. V.). The right renal vein normally reduces to one channel which connects directly with the vena cava. The connection of the left renal vein with the vena cava is more complicated. It involves also the subcardinal-post cardinal anastomosis (Subc. Pc. Anast.). The left sex vein therefore enters the left renal vein by way of the left post cardinal vein (D). The adrenolumbar veins (Adr.) are remnants of the subcardinal veins (Subc.) and may enter the vena cava or the renals.

As a matter of terminology it is well to remember at this point that the variations covered by Huntington and McClure's ontogenetic interpretation of the origin of the variations are not abnormal in the sense of being pathological. They all arise from channels normally present in the embryo and therefore are entirely healthy and, to a degree, normal. It is better, then to use the term atypical in describing these anomalies.

B. The Potential Forms of the Adult Vena Cava Posterior

These possible forms are typed by McClure according to which veins persist from the embryo (figure 1, A, B, C, and D).

1. Type A, persistence of the right post cardinal (A) vein.
2. Type AB, persistence of the right post cardinal (A) and the right supracardinal (B) veins.
3. Type ABC, persistence of the right post cardinal (A), the right supracardinal (B), and the left supracardinal (C) veins.
4. Type ABCD, persistence of the right post cardinal (A), the right supracardinal (B), the left supracardinal (C), and the left post cardinal (D) veins.
5. Type ABD, persistence of the right post cardinal (A), the right supracardinal (B), and the left post cardinal (D) veins.
6. Type AC, persistence of the right post cardinal (A), and the left supracardinal (C) veins.
7. Type ACD, persistence of the right post cardinal (A), the left supracardinal (C), and the left post cardinal (D) veins.

8. Type AD, persistence of the right post cardinal (A), and the left post cardinal (D) veins.

9. Type B, persistence of the right supracardinal (B) vein, the *Normal Vena Cava Posterior (Lumbar)*.

10. Type BC, persistence of the right (B) and left (C) supracardinal veins.

11. Type BCD, persistence of the right supracardinal (B), the left supracardinal (C), and the left post cardinal (D) veins.

12. Type BD, persistence of the right supracardinal (B) and the left post cardinal (D) veins.

13. Type C, persistence of the left supracardinal (C) vein.

14. Type CD, persistence of the left supracardinal (C), and the left post cardinal (D) veins.

15. Type D, persistence of the left post cardinal (D) vein.

The following table shows the number of times each type has been found in the cat and in man up to the time of Huntington and McClure's paper (adapted from Huntington and McClure (3)):

TYPE	CAT	MAN
A	24	4
AB	4	1
ABC	1	0
ABCD	0	0
ABD	0	0
AC	5	0
ACD	1	0
AD	23	1
B	Normal vena cava posterior	
BC	14	71
BCD	0	0
BD	2	0
C	24	17
CD	0	0
D	22	1

Of these types, all have been observed in man or in the cat by Huntington and McClure, or by others reported by them, with the exception of Types ABD, ABCD, BCD, and CD. Type ABCD has been found, however, in the European hedgehog by Hochstetter (1893). The first example of Type ABD has been found by the writer in the cat and is described in this paper. Also a possible Type BCD has been found in the rat and is described later in this paper. The only remaining type to be discovered of the fifteen possible types is CD.

In addition to the fifteen types listed above, another possibility is the persistence of the cardinal collateral vein (figure 1, C. C.). This is the marsupial type of vena cava posterior. It occurs when the vena cava does not pass dorsal to the aorta near the iliac juncture. The vein remains ventral to the aorta all through the lumbar region. Or there may be a combination of the normal and

the marsupial types where the venal cava passes dorsal to the aorta as in the normal vena cava but a branch does continue on the ventral surface and connects with one of the iliac veins beyond the juncture. Theoretically the marsupial type could occur in conjunction with any of the other types listed above. The marsupial type has been found in both man and the cat.

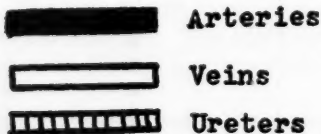
C. The Variations Found in the Cat in This Study

1. *Persistence of the right post cardinal, the right supracardinal, and the left post cardinal veins, Type ABD (figure 2).*

PLATES

Each drawing shows the ventral aspect of the animal. Only those parts are labeled which are of significance in the particular drawing. Figure 7 is completely labeled.

Legend



ABBREVIATIONS

- A., lumbar division of the right post cardinal vein.
- Adr., adrenolumbar vein.
- B., lumbar division of the right supracardinal vein.
- C., lumbar division of the left supracardinal vein.
- C.C., ventral portion of circumumbilical venous ring, the cardinal collateral vein.
- D., lumbar division of the left post cardinal vein.
- E.I.V., external iliac vein.
- I.I.V., internal iliac vein.
- Il., iliac vein.
- Iliol., iliolumbar vein.
- Int.Sprc.Anast., intersupracardinal anastomosis, dorsal to aorta.
- Int.Subc.Anast., intersubcardinal anastomosis, ventral to aorta.
- P.Hep., pars hepatica of the vena cava posterior.
- P.Subc., pars subcardinalis of the vena cava posterior.
- Pc., post cardinal vein.
- Pc.Sprc.Anast., post cardinal-supracardinal anastomosis, lateral to aorta.
- R.V., renal vein.
- Sprc., supracardinal vein.
- Subc., subcardinal vein.
- Subc.Pc.Anast., subcardinal-post cardinal anastomosis, ventrolateral to aorta.
- Subc.Sprc.Anast., subcardinal-supracardinal anastomosis, lateral portion of renal collar.
- S.V., sex vein.

This is the most significant of the variants of the cat series since there is no previous record of a mammal of Type ABD having been found. Figure 2 clearly

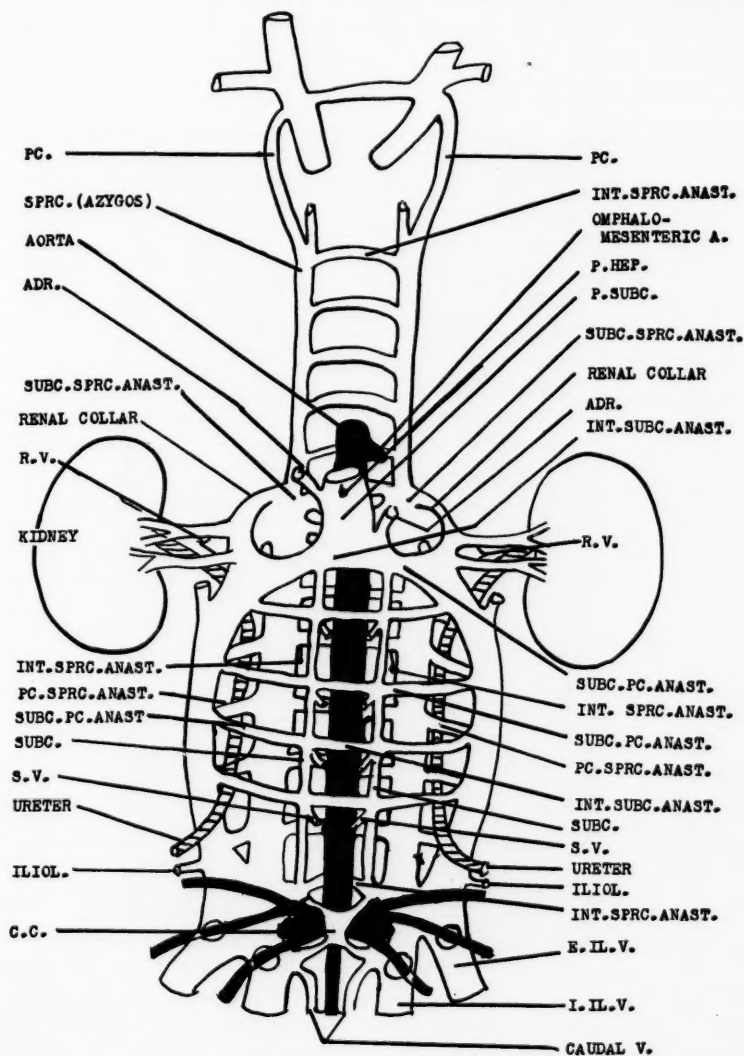


FIG. 1. Composite diagram of embryonic veins of the domestic cat
(After Huntington and McClure, '29)

shows these veins. The large venous channel is the right post cardinal vein (A) because the right ureter passes around it. The middle channel is considered to

be the right supracardinal vein (B) because of its connections to the right post cardinal vein. The third channel is definitely the left post cardinal (D) because the left ureter passes around it. Craniad the vessels connect at the renal level. The left post cardinal vein enters the left renal vein at the place where the left ovarian vein usually enters. This supports McClure's interpretation of the post cardinal's being the proximal portion of the sex vein. Caudad the veins

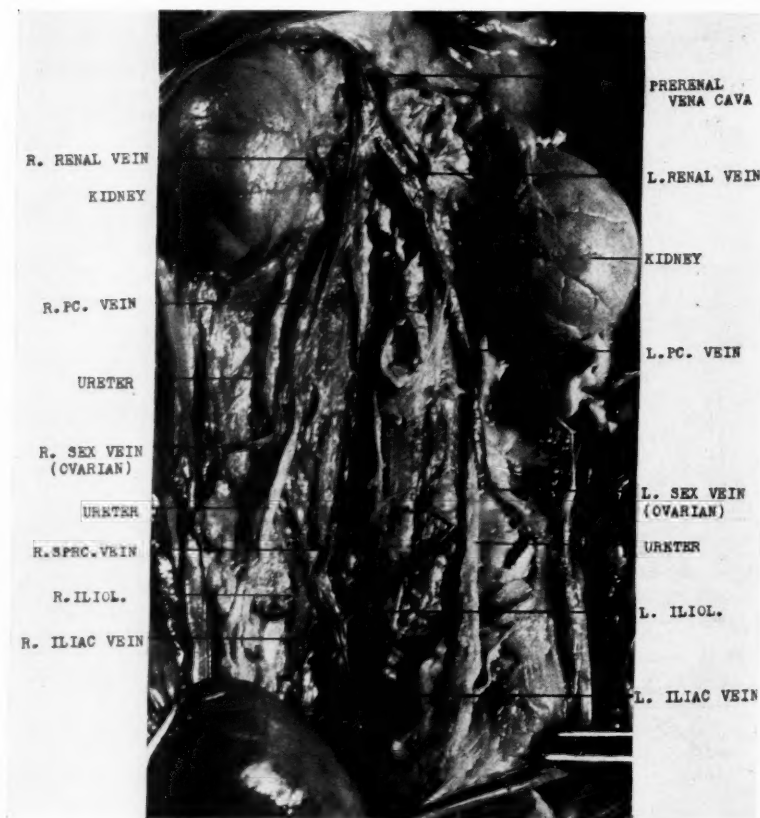


FIG. 2 (a). Photograph of adult cat, type ABD

meet at the iliac level. The main vein at this point is much larger than normal. The aorta has been cut away to show the relations of the veins more distinctly. The double renal veins in evidence on both sides are a relatively common variation in the cat. Figure 1 explains the origin of this condition. The renal veins are double in their connection to the renal collar. A more complete consideration of this matter of multiple renal veins is given below. Also present here is the only example of the ovarian veins' having double connections with the vena

cava. Figure 1 shows the origin of this variation. The sex veins enter at several levels in the embryo. In this case two of the subcardinal-post cardinal anastomoses persist. It is notable that the left ovarian vein enters the left post cardinal vein rather than the left renal vein. This is in keeping with the interpretation of the origin of the proximal portion of the sex vein given above.

Type ABD was found in one cat of this series of thirty-nine.

2. *Persistence of the right post cardinal vein, Type A* (figure 3).

The relation of the right ureter to the venous channel clearly identifies this

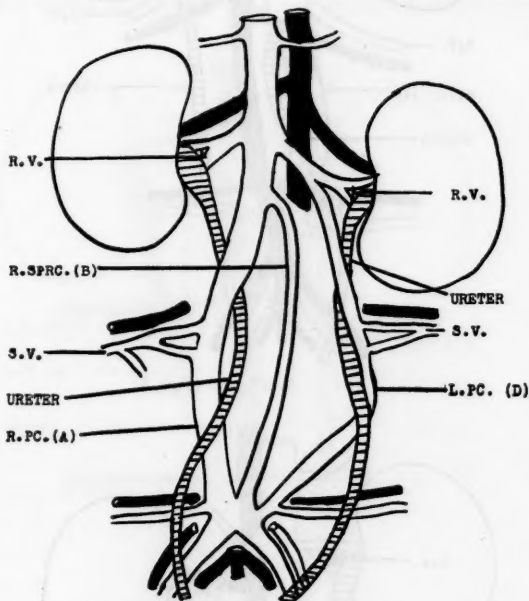


FIG. 2. Adult cat, type ABD

case as Type A. The ureter loops around the vena cava during its descent. Double renal veins are present on the left side.

Type A was found in two cats of this series of thirty-nine.

3. *Persistence of the right post cardinal and the right suprarenal veins, Type AB* (figure 4).

This is an excellent example of the periureteric venous ring mentioned in the previous section. Double renal veins are also in evidence on the right side. An interesting variation is the appearance of a branched condition in the left ovarian vein. The ontogenetic composite diagram (figure 1) will show that in the embryo the sex veins are present at several levels, and in this case two persisted for a short distance rather than only one.

Type AB was found in one cat of this series of thirty-nine.

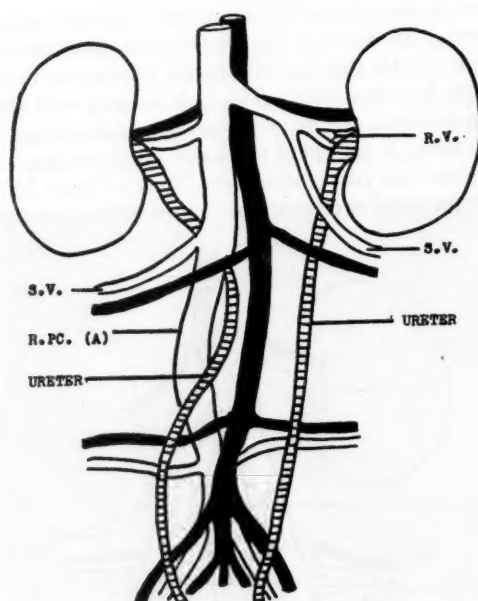


FIG. 3. Adult cat, type A

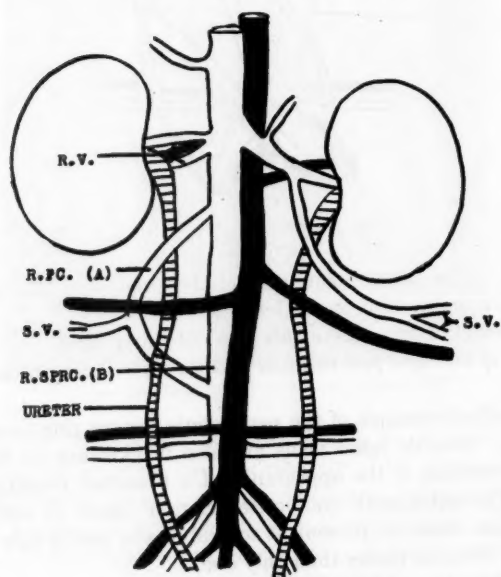


FIG. 4. Adult cat, type AB

4. *Persistence of the right post cardinal and the left supracardinal veins, Type AC (figure 5).*

The right channel is crossed by the right ureter. This shows it to be the right post cardinal vein. The left channel is on the left side of the aorta but not crossed by the ureter. This shows it to be the left supracardinal vein. The relationship of the left channel to the left renal and the left iliolumbar veins gives support to the thesis of Huntington and McClure that intersubcardinal and intersupracardinal anastomoses respectively form the proximal parts of each. Contrary to what would be expected from the discussion of sex veins above, the

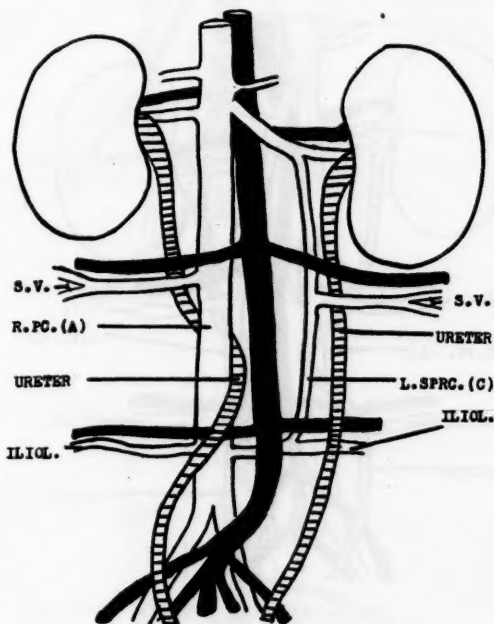


FIG. 5. Adult cat, type AC

ovarian veins both enter the vena cavae directly. The paired condition of these ovarians has been explained above also.

Type AC was found in one cat of this series of thirty-nine. It was observed by Dr. George D. Morgan in 1930 and incorporated in this study as a matter of interest.

5. *Persistence of the right and left post cardinal veins, Type AD (figure 6).*

The ureters point out definitely the origin of the two channels of the vena cava since both channels are crossed by ureters. It is interesting to note that the two channels may be considered to be common iliac veins which do not fuse until the prerenal level, since there is no iliac anastomosis similar to that in figure 4. Double renals are present on the right side.

Type AD was found in one cat of this series of thirty-nine.

6. *Persistence of the right supracardinal vein, the normal vena cava, Type B* (figures 7, 8, 9, 10).

The origins of the particular veins in the normal vena cava were discussed above under the embryological development of the vena cava posterior. The vena cava in this case is formed by the juncture of the common iliac veins dorsal to the juncture of the iliac arteries and then courses cranioventrad around the right lateral surface of the aorta to lie on the ventrolateral surface of the aorta at the renal level.

Type B was found in twenty-nine cats of this series of thirty-nine.

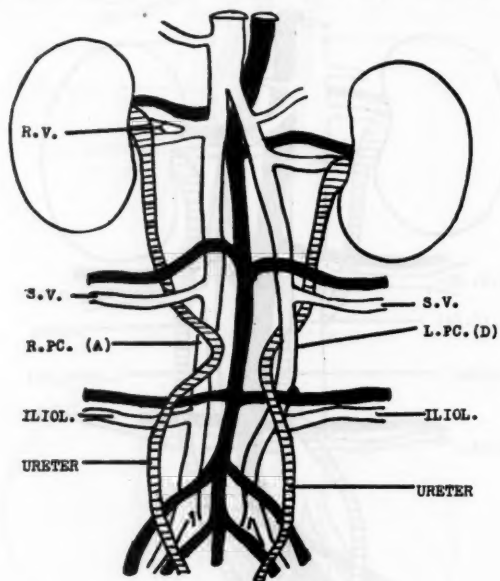


FIG. 6. Adult cat, type AD

Some other anomalies in connection with Type B are of interest. A case was found in which the left kidney had descended to the iliac level, retaining its venous and arterial connections at the usual points (figure 8). This makes the left renal vein over three inches long. The left spermatics pass laterad, then caudad over the ventral surface of the kidney. Here the iliolumbars come off at slightly different levels, probably because of the use of anastomosing channels on different levels in the embryo. Figure 9 shows another atypical connection of the left iliolumbar vein and artery. The multiple renal veins shown in figures 8, 9, and 10 are interesting. They originate in the double renals of the embryo. The case of triple renal veins in figure 10 is evidently a case of the persistence of one of the two renal veins with its further bifurcation and the other without a bifurcation. On this basis a quadruple renal vein is possible.

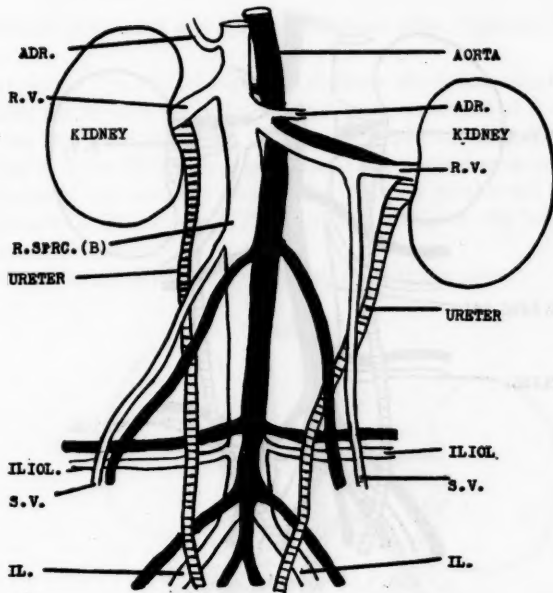


FIG. 7. Adult cat, type B

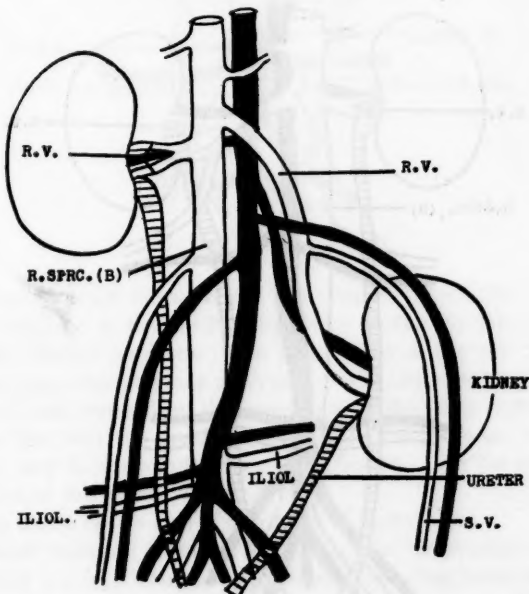


FIG. 8. Adult cat, type B

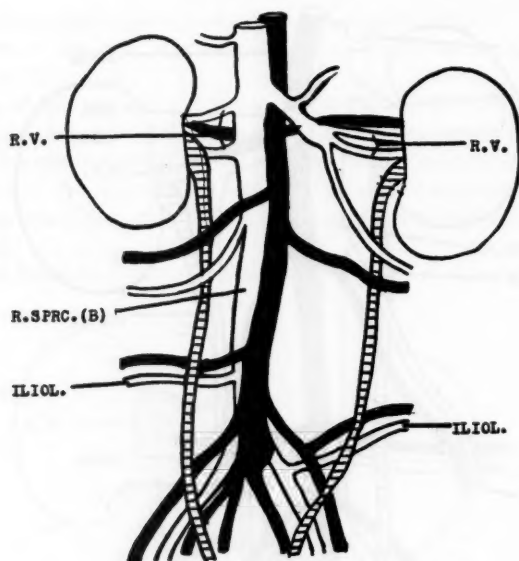


FIG. 9. Adult cat, type B

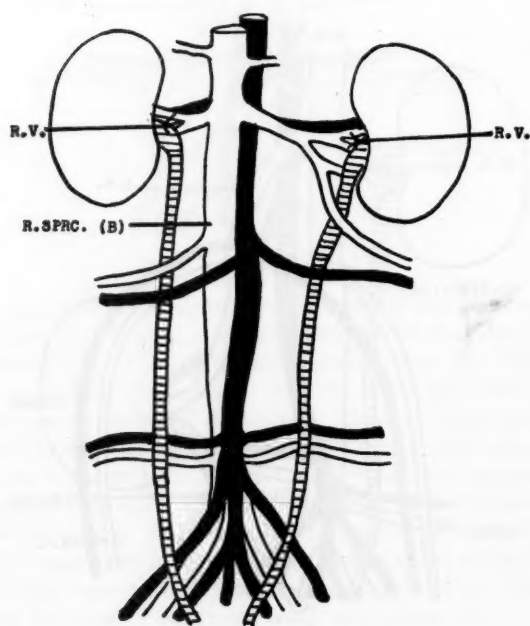


FIG. 10. Adult cat, type B

7. *Persistence of the right and left supracardinal veins, Type BC (figures 11 and 12).*

Figure 11 shows Type BC for a short distance above the usual iliac juncture. The fact that the ureters are in the normal position serves as a check that the two veins are the supracardinals. Figure 12 shows an unusual and somewhat doubtful case of Type BC. The right vein is the normal vena cava. However, the appearance of an auxiliary vein in the position to the left of the aorta is unusual, since it is incomplete. The partial atrophy of the left supracardinal would account for this variant.

Type BC was found in two cats of this series of thirty-nine.

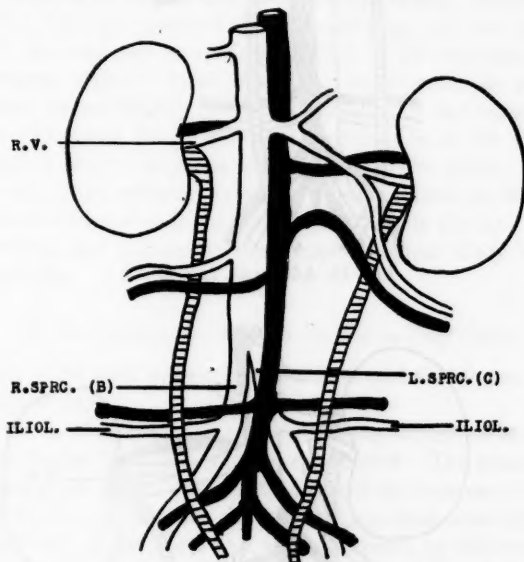


FIG. 11. Adult cat, type BC

8. *Persistence of the left supracardinal vein, Type C (figure 13).*

The vena cava here is identified by its course on the left side of the aorta as they exchange relative positions. The connections of the sex veins complete the effect of having a mirror image of Type B. The fact that the positions of the sex veins have been reversed by the persistence of the other supracardinal vein points to the idea that the proximal portions of the sex veins may be supracardinal when they do not join the vena cava directly. See the conclusion for a fuller discussion of this point.

Type C was found in two cats of this series of thirty-nine.

The significant variation of this series is, of course, the example of Type ABD (figure 2), which is a type hitherto unmentioned as having been observed in any mammal. A more complete interpretation of the variations in the cat is given in the conclusions below.

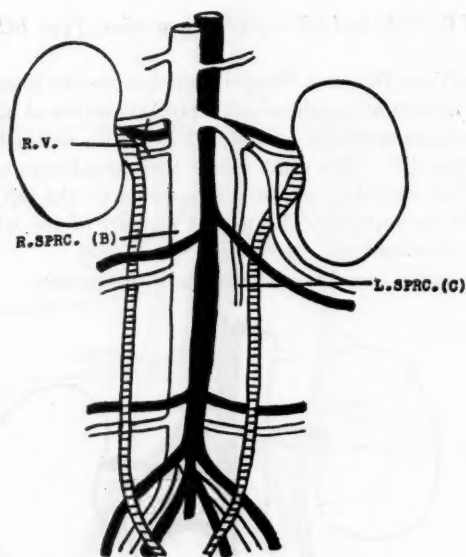


FIG. 12. Adult cat, type BC

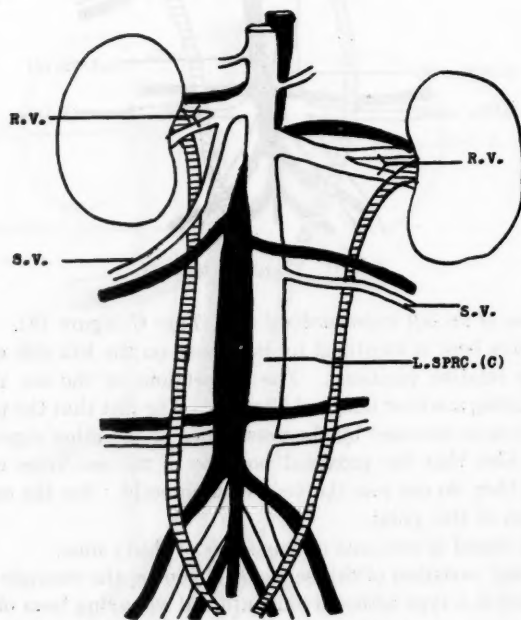


FIG. 13. Adult cat, type C

III. VARIATIONS OF THE VENA CAVA POSTERIOR OF THE RAT

A.

Unfortunately it is not possible, because of the unavailability of sufficient reference material, to give an accurate account of the ontogenetic development of the vena cava posterior of the rat. For the purposes of this study the assumption is that the rat follows the same course of development as the cat, with these two exceptions. Begg (1) points out that the Wolffian bodies in the rat are unusually small in all stages of the development. This leads, according to Begg, to a much greater simplicity in the development of corresponding blood vessels and should limit the number of variations found. Reagen (6), writing much later, says that the principal difference between rats and other mammals in ontogeny is the relatively early dropping out of the two post cardinal veins in the mesonephric region. Aside from these statements, the general opinion seems to be that the rat follows the typical mammalian development. Another possibility for differences lies in the usual classification of the Rodentia as the order immediately below Carnivora in the phylogenetic series. Any difference that might occur in the ontogeny of the two forms related to this classification would be in the direction of more primitive conditions in the rat. However, this is only conjecture, and a more complete embryological study is necessary to establish its validity.

*B. The Variations Found in the Rat in This Study**1. Persistence of the right and left supracardinal and the left post cardinal veins, Type BCD (figure 14).*

This specimen is of a type not recorded in the literature heretofore. The classification of this as Type BCD may be questioned. The reasons for classifying it as such are given here. The two branches of the vena cava which continue on to the iliac region are definitely the two supracardinal veins (B and C), since they lie on each side of the aorta and are not crossed by either of the ureters. The left iliolumbar normally passes dorsal to the ureter. In this rat the iliolumbar passes ventral to the ureter. The only satisfactory way to explain this anomaly is by considering the proximal portion of the left iliolumbar vein as the lateral half of a periureteric venous ring of which the caudal portion has dropped out. It is evident that the left iliolumbar vein would pass dorsal to the ureter if this connection to the vena cava were present. Therefore the proximal portion of the left iliolumbar vein must be the left post cardinal vein (D).

This explanation makes necessary some comment on the left ovarian vein. The fact that it enters the left renal vein directly indicates some further changes in development. McClure's interpretation states that the left sex vein joins the left post cardinal vein (D) before entering the left renal vein. One explanation of this case is the persistence of the left subcardinal vein, and its connection with the renal collar. Then later in development the connection of this vein with the left renal shifts to a point lateral to the entrance of the left post cardinal

vein. Figure 1 shows this possibility. The left periureteric venous ring, which is a very rare occurrence, is unfortunately not present.

Type BCD was found in one rat of this series of thirty-six.

2. *Persistence of the right post cardinal, the right supracardinal, and the left supracardinal veins, Type ABC* (figure 15).

The right channel of the vena cava is identified as the right post cardinal vein by the relation of the ureter which loops around the vein. The remaining smaller channels must be the supracardinals because the ureter passes laterally. The left sex vein here enters the left renal vein directly as McClure's interpretation states.

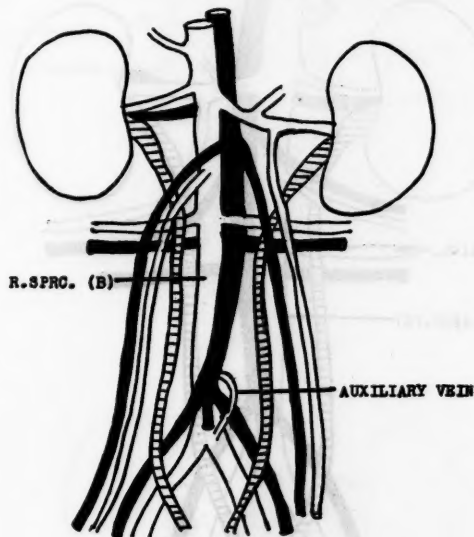


FIG. 16. Adult rat, type B

Type ABC was found in one rat of this series of thirty-six.

3. *Persistence of the right supracardinal vein, Type B* (figures 16 and 17).

This is the normal vena cava for the rat. It will be noticed that there are several points of difference between the rat and the cat. The iliolumbar veins and arteries connect with the main vessel considerably cranial of the position in the cat. The left adrenolumbar vein enters the left renal instead of the vena cava directly. The arterial iliac juncture is more cranial with relation to the venous iliac juncture than is the case in the cat.

Type B was found in twenty-one rats of which two show interesting anomalies. Figure 16 shows an auxiliary vein at the level of the iliac juncture. It arises from the vena cava, passes laterally around the left common iliac artery and returns to the vena cava caudally. A consideration of figure 1 will show two possibilities for such an occurrence. Persistence of the portion of the iliac veins which is lateral to the iliac arteries on the left side could result in this condition.

Figure 17 shows an entirely normal vena cava posterior lacking the left ilio-lumbar vein. Some abnormal embryological condition has probably occluded or prevented the growth of the left ilio-lumbar early in the development so that some other vein has taken over its function. The specimen seems normal in every other respect.

4. *Persistence of the right and left supracardinal veins, Type BC* (figures 18, 19, 20, 21, and 22).

This is the usual type of double vena cava posterior where the vena cavae are

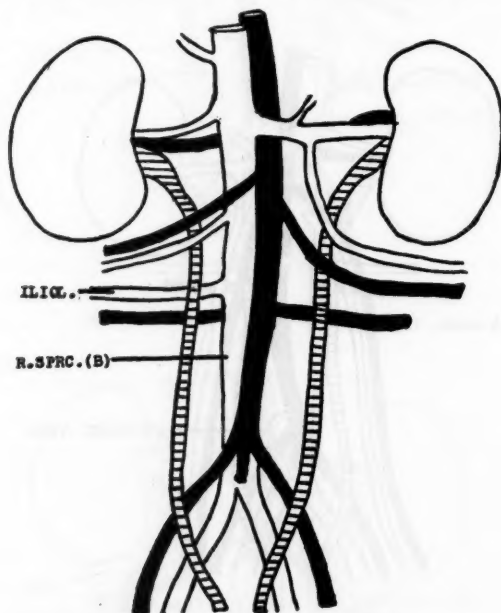


FIG. 17. Adult rat, type B

not crossed by the ureters. Type BC was found in thirteen rats of this series of thirty-six. These, however, break down into several sub types as follows.

Figure 18 shows the normal vena cava persisting with a small collateral channel identified as the left supracardinal since it is not crossed by the ureter. The left ilio-lumbar vein enters the right supracardinal with no connection with the left supracardinal vein. There evidently was a connection with the left supracardinal earlier in development which dropped out. The left supracardinal seems to contribute to the left sex vein as was observed in the cat. Also in this specimen is the only case of double renals in this series. One case of Type BC as shown in figure 18 was found.

Figure 19 shows the most frequently occurring example of Type BC. The

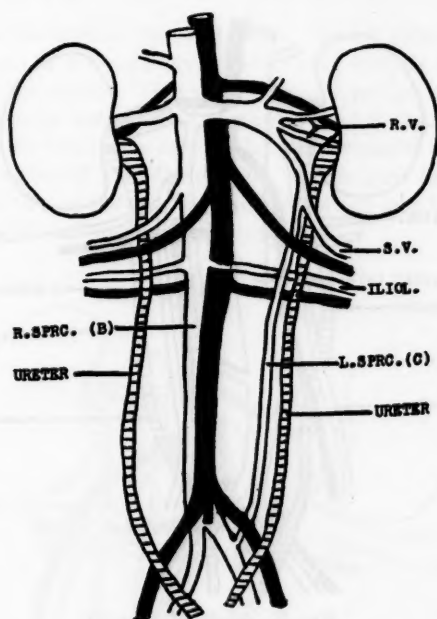


FIG. 18. Adult rat, type BC

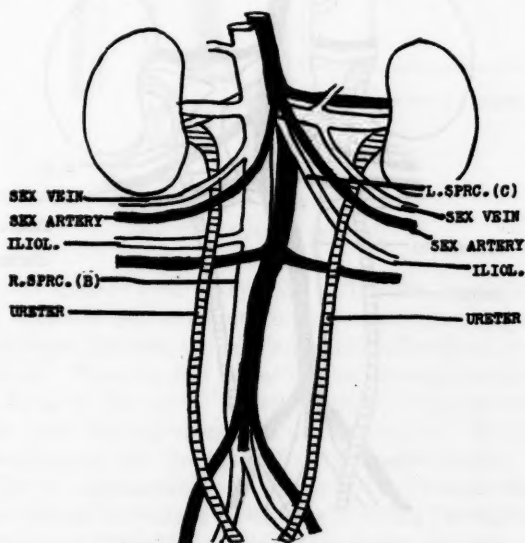


FIG. 19. Adult rat, type BC

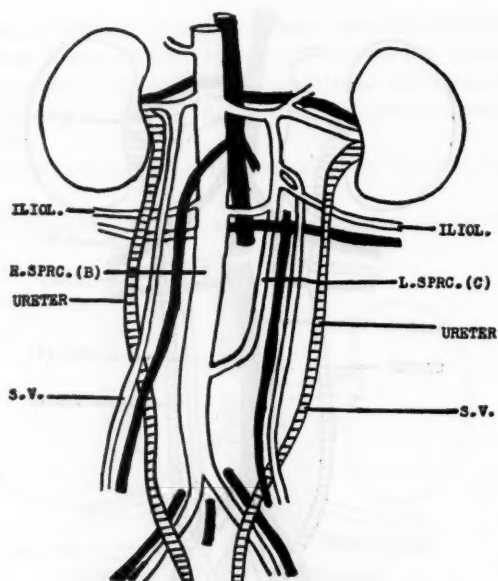


FIG. 20. Adult rat, type BC

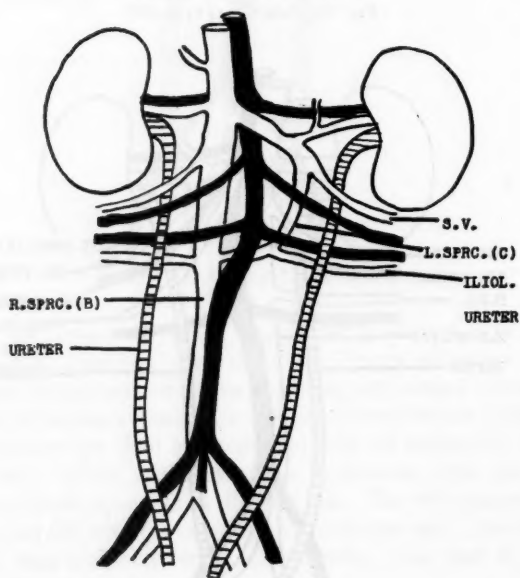


FIG. 21. Adult rat, type BC

vena cava itself is the normal type. However, the left iliolumbar vein enters the left renal instead of the vena cava directly, but without changing from its normal relation to the ureter. This suggests that a portion of the left supracardinal vein remains as the proximal portion of the left iliolumbar vein. The position of the left sex vein here points to the involvement of the left post cardinal vein in the formation of the left sex vein. In this same figure is also shown an anomalous condition of the spermatic arteries which was found in one case. This form of Type BC was found in eight rats.

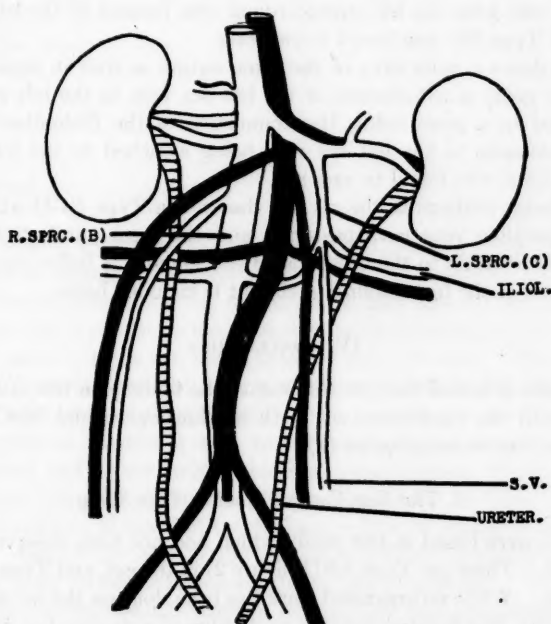


FIG. 22. Adult rat, type BC

Figure 20 shows another form of Type BC. The left supracardinal vein extends from the left renal vein to its juncture below the iliolumbar level. There is also an anastomosis between the two supracardinals ventral to the aorta at the iliolumbar level. From figure 1 we see that an intersupracardinal anastomosis would pass dorsal to the aorta. Therefore, this anastomosis must consist of portions of the post cardinal-supracardinal anastomoses, the post cardinal-subcardinal anastomoses, and the intersubcardinal anastomosis. Also the left sex vein joins the left supracardinal vein in contrast to its usual entry of the left renal vein. An unusual anomaly is shown here involving the right sex vein. In these animals whenever the right supracardinal is present the right sex vein enters

the vena cava directly. Here, however, it enters the right renal directly. We saw above that the proximal portion of the right sex vein was formed from the right post cardinal vein. Then by a craniocaudal elongation of the renal collar the point of entry into the vena cava is shifted to a point on the right supracardinal channel farther caudal. Presumably then if this shifting did not result in this change in location, the right sex vein would continue to enter the right renal vein as in the embryonic condition. This seems to be the best explanation. This form of Type BC was found in one rat.

Figure 21 shows a small circumaortic venous ring not involving either ureter. The left sex vein joins the left supracardinal vein instead of the left renal vein. This form of Type BC was found in two rats.

Figure 22 shows a vena cava of the same nature as that in figure 21. Here, however, the point of attachment of the left sex vein to the left supracardinal has descended to a point below the connection of the iliolumbar vein. This practically amounts to the left sex vein being attached to the left iliolumbar vein. This form was found in one rat.

The significant findings in the rat are these: The Type BCD which is a new type of mammalian vena cava posterior, and the great number of examples of Type BC with relation to the other variations found. A fuller consideration of the significance of the forms found in the rat is included below.

IV. CONCLUSIONS

In conclusion it is well that we summarize the findings in this study and compare them with the conclusions set forth in Huntington and McClure's monograph on the vena cava posterior (3).

A. The New Forms Found in This Study

Two forms were found in this study which had not been observed previously any mammal. These are Type ABD (figure 2) in the cat, and Type BCD (figure 14) in the rat. While no organized work has been done on the rat similar to that done on the cat, this isolated instance is of value as a mammalian form even if it cannot be compared with a large number of other rat forms. McClure states that at the time of his study only Types ABD, BCD, and CD remained undiscovered in mammalian forms. Now only Type CD remains to be found.

B. A Summary of the Evidence Concerning the Type Variants

There is an important difference in the relative frequency of the occurrence of certain types in the cat and in the rat. It is interesting that the variations in the cat are spread out among the different types of variants, while the variations in the rat are grouped heavily in one type.

The following table shows the frequency of occurrence of the various types in these series:

TYPE	CAT	RAT
A	2	0
AB	1	0
ABC	0	1
ABCD	0	0
ABD (New)	1	0
AC	1	0
ACD	0	0
AD	1	0
B	29	21
BC	2	13
BCD (New)	0	1
BD	0	0
C	2	0
CD	0	0
D	0	0
Total.....	39	36

The question of differences in the frequently appearing types of variations in the two species brings up several possibilities. Considering Huntington and McClure's results concerning the cat and man, and also the cat and rat of this study, we see that Type BC is the most frequently occurring in the rat, Types A, AD, BC, C, and D, in the cat, and Types BC and C in man. The only instance of type ABCD having been found is in the European hedgehog which is a member of the lowest order of the Eutheria.

These degrees of occurrence seem to correlate with the advancing complexity of the organism and higher rank in the phylogenetic series. While investigation has not shown the true significance of the appearance of Type ABCD in the hedgehog, the failure of that most rudimentary type to appear in higher forms is significant. Also in the case of the rat an insufficient quantity of material is available to come to any conclusions about rats in general.

Concerning the representativeness of this sample, we must consider the source of the various animals. The rats were procured from a supply house which probably got them from a breeder of animals for scientific purposes. This suggests the inbreeding of a stock found to be satisfactory in general scientific work. However, since any inbreeding tends to limit the number of variations found in the animal, it would most probably seriously limit the finding of a representative series of variations. In the case of the cats, however, and the specimens of man, it is generally true that the individuals are those picked up at random with no control whatsoever over the breeding. This latter would tend to give a sample more nearly representative of the entire population, which is, of course, the aim of an investigator in this field. Thus it is that there is much more uniformity in the sample of rats than of cats. How much of this is due to the selection and how much is due to the characteristics of rats themselves is impossible to tell from

this point. Because the rat is a typical mammal, the chances seem to be that breeding played a greater part. This same reasoning should apply to the case of the double renal veins and to the double sex veins.

The factor noted by Reagan above may have bearing here. The early dropping out of the old post cardinal veins in the normal rat would in part explain the rarity of types involving A and D in this series.

Be this as it may, there remains the difference between the results found in the cat and in man and the absence of Type ABCD in animals above the hedgehog. The increasing specialization of the higher forms involves an earlier dropping out of organs in the embryo which do not persist in the adult. In keeping with the order of dropping out of the venous channels in the developing embryo described above, the ones most likely to persist are the two supracardinal veins. Therefore in man the proportion of atypical veins would be mostly BC and C, and in the cat, more of the A and D combinations than in man. This proves to be the case if the samples presented by Huntington and McClure are typical. This correlation, however, does not indicate a cause and effect relationship between these two factors, and it may be that some other factor is more important. Since the rat and cat are so close together in the phylogenetic series it is questionable whether any differences in variation could be attributed to this factor, but it is worth keeping in mind.

C. A Summary of the Evidence Concerning the Renal Veins

The following table shows the occurrence of multiple renal veins in both forms:

Renal Veins	Cat	Rat
Normal.....	19	35
Right double.....	12	0
Left double.....	2	1
Right double, left triple.....	1	0
Total.....	39	36

An interesting point to come out of this tabulation is the difference in the frequency of occurrence of double renal veins between the right and left sides of the cat. There are eighteen cases of double right renals and only eight cases of double left renals. This seems to follow from the ontogenetic diagram (figure 1). Since the right side of the renal collar persists in the adult instead of the left, the likelihood of the right renal veins retaining their original double connection with the vena cava is greater than that of the same thing happening on the other side. The original double left renal veins are only the distal section of the adult left renal vein.

The occurrence of double renals in the two forms is interesting. Twenty cats had some degree of double renal veins, but only one rat had double renals. This

fact points to some difference in the ontogeny of the two species. This fact also fits in with the idea expressed above that the manner of breeding the rats probably was such that it tended toward uniformity.

D. A Summary of the Evidence Concerning the Sex Veins

1. The Double Sex Veins.

This table shows the occurrence of double sex veins in both series:

SEX VEINS	CAT	RAT
Double proximally.....	1	0
Double distally.....	2	0

The occurrence of double sex veins is more rare than that of double renals. There are three cases in the cat series (figures 3, 4, and 5). The double distally type might be considered merely premature branching but the source of the bifurcation in the embryo seems to be similar. Figure 1, again, shows how this may have happened. There were no such instances in the rat. This finding is in harmony with that concerning the double renals and the same causative factors apply.

2. The Left Sex Veins.

This table shows the points of connection of the left sex vein with the vena cava:

LEFT SEX VEINS ENTER THE:	CAT	RAT
Left sprc. (C) when there is no left p.c. (D).....	2	4
Left p.c. (D).....	2	0
Left renal when there is a left sprc. (C).....	1	9
Left renal when there is a left p.c. (D).....	0	1

Here appears a very interesting situation in which there are many possible ways of interpreting the composite plan of McClure and Huntington. They state that the sex veins of the adult are formed from the embryonic sex veins, a subcardinal-post cardinal anastomosis, and a segment of the post cardinal vein which leads to the renal vein. In the case of the right sex vein the evidence here supports their explanation that a craniocaudal elongation results in the right sex vein entering the right supracardinal vein directly when the right supracardinal vein persists in the adult without the right post cardinal vein. There is one exception to this statement. Figure 20 shows a case of the right sex vein entering the right renal vein when the right supracardinal persists. This was explained above as the lack of shifting of the vein caudad when the renal collar elongates. There is no evidence that a different embryonic channel was employed, however. Therefore it is the origin of the left sex vein which is open to speculation on the basis of the evidence here.

The two cases in the cat and the four cases in the rat in which the left sex vein opens into the left supracardinal vein, when the left post cardinal does not persist, seem to contradict McClure's emphasis on the left post cardinal's part in the formation of the left sex vein. Two adjustments can be made to bring these in line with his view. There might have been a craniocaudal elongation of the left renal collar (ventral portion) to shift the entry of the left sex vein caudad. Or the left post cardinal vein might be actually incorporated in the formation of the vein which appears to be the left supracardinal vein, above the point of entry of the sex vein. If this latter occurred without causing a ureteric crossing of the caval vein, it would be impossible to determine exactly which had happened. Another explanation equally plausible but outside of McClure's hypothesis is the idea that the left sex vein in these cases was formed from the embryonic sex vein, a subcardinal-post cardinal anastomosis, a post cardinal-supracardinal anastomosis, and a portion of the left supracardinal vein, which joined the renal collar. Logically this might also occur in cases of the normal vena cava.

There are two cases in the cat where the left sex vein joins the left post cardinal directly. This follows from McClure's interpretation. Also the one case in the cat and nine cases in the rat, where the left sex vein joins the left renal directly even though the left supracardinal vein is present, give support to McClure's theory.

An interesting anomaly is the case of Type BCD in the rat (figure 22) where the left sex vein opens into the left renal when the left post cardinal persists and extends down to the ilio-lumbar level. This does not lend itself to McClure's theory and seemingly must be classified as the persistence of a subcardinal vein up to the level of the renal collar, where it shifted laterally to a point lateral to the entrance of the left post cardinal vein as the renal collar changed its form.

From this evidence it is easy to see that the development of the left sex vein is not as simple as would be inferred from McClure's description. As F. P. Reagan states at the close of his summary of research on the development of the vena cava inferior, "This, however, may be said: whether we wish it or not, the formation of the vena cava is a much more complicated process than any existing account would indicate." The results of this study do, however, point to McClure's explanation as that which fits the majority of the variants of the left sex vein. The other cases suggest a more complicated developmental pattern.

V. GENERAL SUMMARY

This paper has presented the results of a study of thirty-nine cats and thirty-six rats in the light of previous work done on the mammalian vena cava posterior. Two types, predicted by Huntington and McClure (3) but not found by them, were found in these groups of animals: Type ABD and Type BCD. The significance of the different relative frequencies of occurrence of different types in the two species was considered and some speculations were made as to the causes. Also some comment was made concerning Huntington and McClure's interpretation of the development of the vena cava posterior, especially the left sex vein. The discovery of the two new types made this work most interesting.

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The first of these is the fact that the United States is a young nation. It is only about 150 years old, and its history is therefore a history of rapid growth and change. The second is the fact that the United States is a large nation. It covers a vast area of land, and its population is one of the largest in the world. The third is the fact that the United States is a diverse nation. It is made up of many different peoples, languages, and customs. The fourth is the fact that the United States is a free nation. It is a land of liberty, where the rights of the individual are protected by the law. The fifth is the fact that the United States is a powerful nation. It has a strong military and a powerful economy. The sixth is the fact that the United States is a nation of opportunity. It is a land where anyone can succeed if they work hard enough. The seventh is the fact that the United States is a nation of hope. It is a land where the future is bright and the possibilities are endless. The eighth is the fact that the United States is a nation of faith. It is a land where people believe in the power of God and the goodness of man. The ninth is the fact that the United States is a nation of love. It is a land where people care for each other and work together for the common good. The tenth is the fact that the United States is a nation of peace. It is a land where the people live in harmony and the world is at peace.

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